

Project Title: Installation and Further Development of a Fully Automated Global Centroid Moment Tensor Code at the National Earthquake Information Center

External Grant Award Number: 05HQGR0003

Principal Investigator: Jarmila (Jascha) Polet
Institute of Crustal Studies
University of California
Santa Barbara, CA 91306
Tel.: (805) 893-2820
E-mail: polet@crustal.ucsb.edu

Key words: Source characteristics, Real-time earthquake information

Investigations Undertaken

We have installed the autoCMT software, which computes fully automated global Centroid Moment Tensors, at the National Earthquake Information Center. This system had been operating successfully at Caltech but ceased to be supported there. For the past decade, this system had provided a valuable service as one of the few, if not only, providers of completely automatic reliable CMT solutions for worldwide events greater than magnitude 5.5. In addition to successfully installing and running the system as it existed at the Caltech Seismological laboratory, we have also started the implementation of further improvements that will result in a more efficient, more reliable and faster system to deliver completely automatic CMT solutions for worldwide large earthquakes.

The previously implemented systems at the NEIC either do not run fully automatically, do not determine a centroid time or location and/or are less suited for great earthquakes, because of their reliance on relatively short period body waves, in contrast to the very long period surface waves used by the autoCMT. Thus the autoCMT system fulfills an important need and, based on its unique strengths, is complementary to existing methods at the NEIC. The long period nature of the seismic waveform data the system uses as its input has the additional advantage that the method is relatively insensitive to the effects of timing errors, mislocation, and lateral heterogeneity. The autoCMT determines reliable moment magnitude estimates and mechanisms, and performs particularly well for events greater than 7.0. It is especially notable that this fully automatic method performs equally well as its human reviewed counterparts for most large events, even with its input minimum of only 12 waveforms.

Results

We have implemented the existing autoCMT software at the NEIC, where it has been running, fully automatically, over the past several months. Further integration with routine NEIC operations and the Hydra system is currently proceeding.

Two main changes were made to the existing system (see Figure 1): one involved the triggering mechanism, the other the waveform retrieval mechanism. Previously, the autoCMT was triggered by an event notification E-mail from the NEIC. A new trigger was implemented with the help of Dr. Paul Earle, using a cubic message sent by the

NEIC event locator. This message is parsed to check for a minimum initial magnitude of 5.5 and only considers reviewed event locations. The main improvement to the system is the new waveform retrieval module. Access to the waveform data has been facilitated by the use of the NEIC wavepool. Not only is access to the data now much faster than by having to use the IRIS data depository, it has also proven much more reliable and thus a further speed increase is achieved because fewer quality checks of the waveforms are needed. The waveform acquisition is now no longer a bottleneck in the autoCMT process and the main performance limit on how fast a CMT solution can be produced for an earthquake is the propagation speed of the long period surface waves needed for the inversion. This translates into a time-to-CMT for the average earthquake (dependent on location and station distribution) of only 45 minutes after origin time. Since sufficient waveform data (12 traces or more) will always eventually be available via the USGS wavepool, every earthquake-trigger will now produce a CMT solution.

In addition to these important improvements to the performance of the system in terms of data access and processing, we have also started to investigate ways to improve the quality assessment of the CMT solutions and, closely related, improve the solution itself through the use of iterative inversions and criteria for the selection of waveforms to use as input in the inversion. To examine the best combination of outlier-removal and number of used data traces, based on criteria either involving absolute trace variance reduction or trace variance reduction with respect to overall variance reduction after the initial inversion, we have implemented three different near real-time inversions. After a short period of testing, it appears that the most reliable near real-time solution is the one from an inversion that discards those traces with a low absolute variance reduction (less than 3%) from an initial inversion using all available waveforms. Therefore, this is our currently preferred near real-time solution, provided the number of input waveforms after the selection criteria have been applied still exceeds a lower limit of 12. We have additionally started to investigate the possibility of using a jackknifing method to give an improved indication of the reliability of the CMT. For near real-time functionality, we will implement a set of inversions with a reduced channel list. Due to time considerations, we limit the number of inversions to five or less. To this end, we remove one station per inversion if the number of channels available is limited to 20 or less or alternatively, we carry out inversions on subsets of channels if more channels are already available.

The autoCMT solutions also have a valuable use as a near real-time starting point for full finite fault rupture inversions and strong ground motion predictions of great earthquakes. To this aim, further integration with Dr. Chen Ji's software at the NEIC is possible and planned in the near future.

Non-technical Summary

We have implemented the autoCMT software at the National Earthquake Information Center. This system provides completely automatic source mechanisms for worldwide large earthquakes, performing particularly well for events greater than 7.0. In addition to installing and operating the system for the past several months, we have started the implementation of further enhancements. Waveform access and processing has significantly improved, providing both more reliable as well as much faster source characterizations. We have also started to investigate techniques to improve the quality

assessment of the inversion results and, closely related, refine the solution itself through iterative inversions and waveform selection procedures.

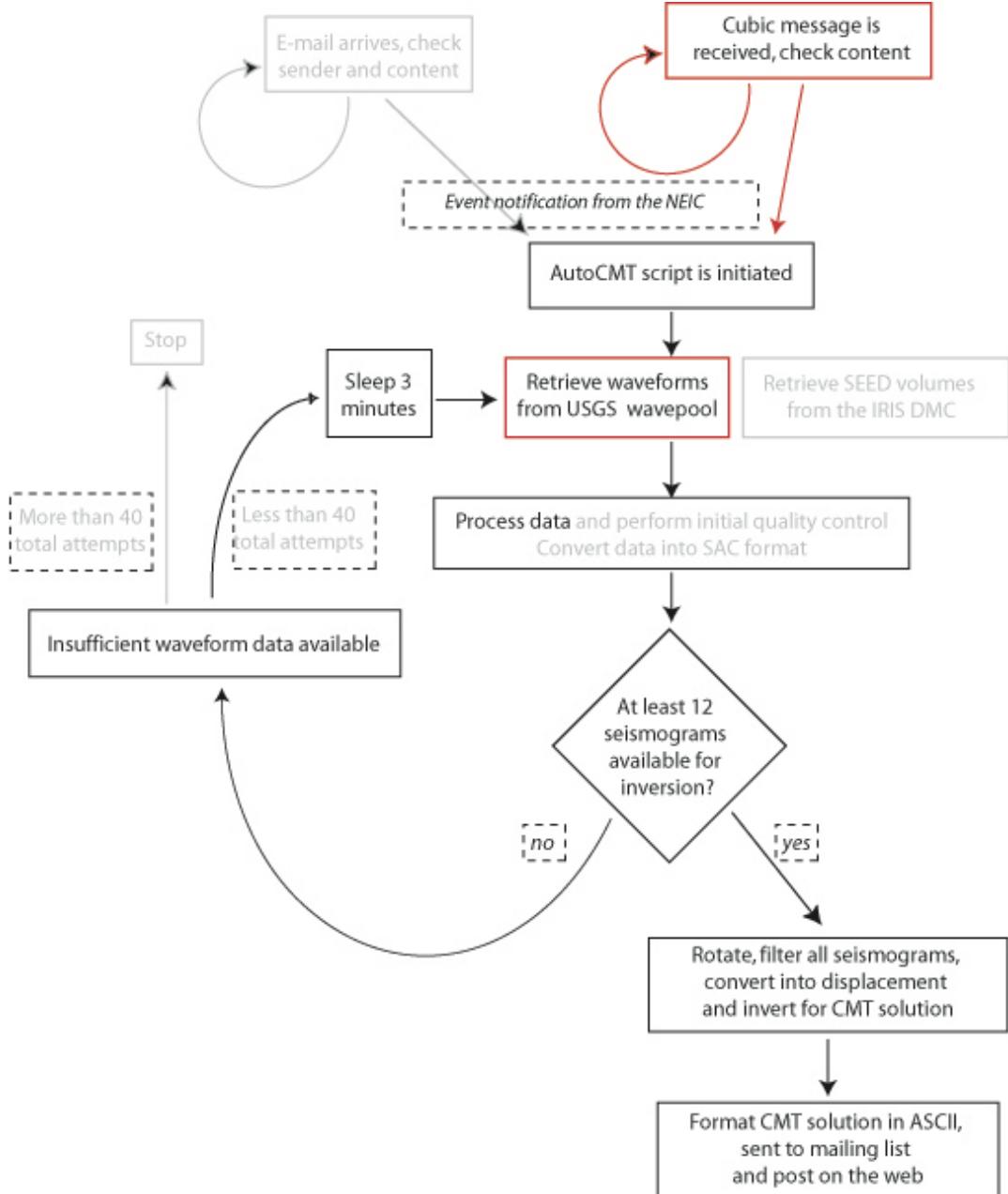


Figure 1: Simple flowchart of the autoCMT system. The components of the original system (as operational as the Caltech Seismological Laboratory) that were replaced are shown in light gray; the black color shows the system as implemented at the National Earthquake Information Center. The main modifications were made to the triggering mechanism and the waveform access and processing module.